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► **To cite this version:**

Marcin Marszalek, Cordelia Schmid, Hedi Harzallah, Joost van de Weijer. Learning Object Representations for Visual Object Class Recognition. Visual Recognition Challenge workshop, in conjunction with ICCV, Oct 2007, Rio de Janeiro, Brazil. 2007. inria-00548669

HAL Id: inria-00548669

<https://inria.hal.science/inria-00548669>

Submitted on 20 Dec 2010

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Learning Representations for Visual Object Class Recognition

Marcin Marszałek Cordelia Schmid
Hedi Harzallah Joost van de Weijer

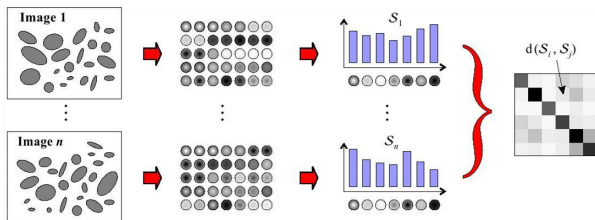
LEAR, INRIA Grenoble, Rhône-Alpes, France

October 15th, 2007

Bag-of-Features

Zhang, Marszałek, Lazebnik and Schmid [IJCV'07]

- Bag-of-Features (BoF) is an orderless distribution of local image features sampled from an image
- The representations are compared using χ^2 distance

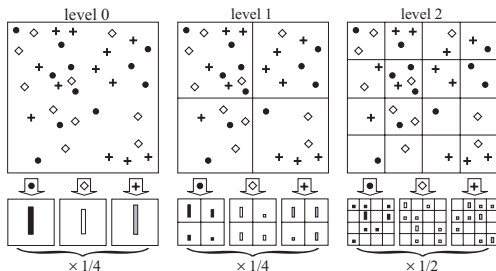


- Channels can be combined to improve the accuracy
- Classification with non-linear Support Vector Machines

Spatial pyramid

Lazebnik, Schmid and Ponce [CVPR'06]

- Spatial grids allow for locally orderless description
- They can be viewed as an extension to Bag-of-Features



- They were shown to work on scene category and object class datasets

Combining kernels

Bosch, Zisserman and Munoz [CIVR'07], Varma and Ray [ICCV'07]

- It was shown that linear kernel combinations can be learned
 - Through extensive search [Bosch'07]
 - By extending the C-SVM objective function [Varma'07]
- We learn linear distance combinations instead
 - Our approach can still be viewed as learning a kernel
 - We exploit the kernel trick (it's more than linear combination of kernels)
 - No kernel parameters are set by hand, everything is learned
 - Optimization task is more difficult

Our approach: **large number** of channels

- In our approach images are represented with several BoFs, where each BoF is assigned to a cell of a spatial grid
- We combine various methods for sampling the image, describing the local content and organizing BoFs spatially
- With few samplers, descriptors and spatial grids we can generate tens of possible representations that we call “channels”
- Useful channels can be found on per-class basis by running a multi-goal genetic algorithm

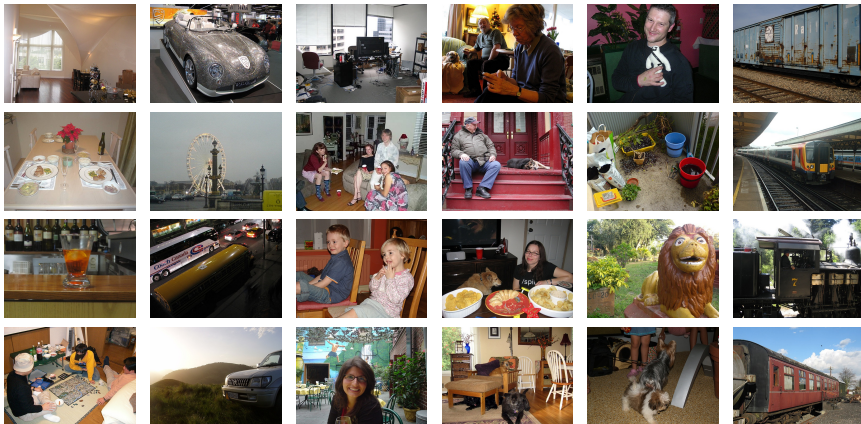
Overview of the processing chain

Image \rightarrow Sampler \times Local descriptor \times Spatial grid \Rightarrow Fusion \rightarrow Classification

- Image is sampled
- Regions are locally described with feature vectors
- Features are quantized (assigned to a vocabulary word) and spatially ordered (assigned to a grid cell)
- Various channels are combined in the kernel
- Image is classified with an SVM

PASCAL VOC 2007 challenge

Image → Sampler × Local descriptor × Spatial grid ⇒ Fusion → Classification



bottle

car

chair

dog

plant

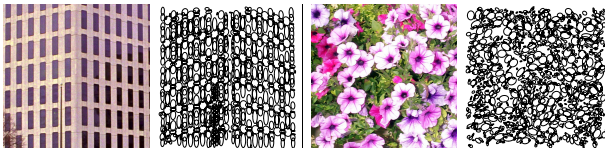
train

Image sampling

Image \rightarrow **Sampler** \times Local descriptor \times Spatial grid \Rightarrow Fusion \rightarrow Classification

- Interest points detectors

- Harris-Laplace — detects corners [Mikołajczyk'04]
- Laplacian — detects blobs [Lindeberg'98]



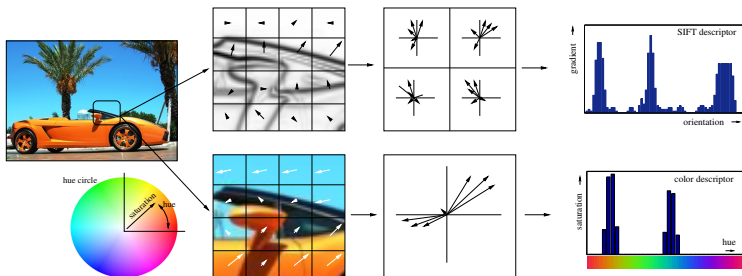
- Dense sampling

- Multiscale grid with horizontal/vertical step of 6 pixels (half of the SIFT support area width/height) and scaling factor of 1.2 per scale-level

Local description

Image \rightarrow Sampler \times **Local descriptor** \times Spatial grid \Rightarrow Fusion \rightarrow Classification

- SIFT — gradient orientation histogram [Lowe'04]
- SIFT+hue — SIFT with color [van de Weijer'06]

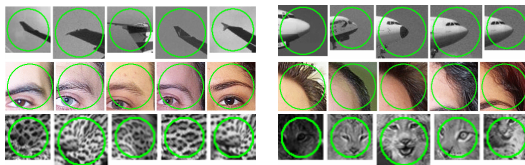


- PAS — edgel histogram [Ferrari'06]

Spatial organization

Image \rightarrow Sampler \times Local descriptor \times **Spatial grid** \Rightarrow Fusion \rightarrow Classification

- Visual vocabulary is created by clustering the features using k-means ($k = 4000$)



- Spatial grids allow to separately describe the properties of roughly defined image regions
 - 1x1 — standard Bag-of-Features
 - 2x2 — defines four image quarters
 - horizontal 3x1 — defines upper, middle and lower regions

Support Vector Machines

Image \rightarrow Sampler \times Local descriptor \times Spatial grid \Rightarrow Fusion \rightarrow Classification

- We use non-linear Support Vector Machines
- The decision function has the following form

$$g(x) = \sum_i \alpha_i y_i K(x_i, x) - b$$

- We propose a multichannel extended Gaussian kernel

$$K(x_j, x_k) = \exp \left(- \sum_{ch} \gamma_{ch} D_{ch}(x_j, x_k) \right)$$

- $D_{ch}(x_j, x_k)$ is a similarity measure (χ^2 distance in our setup) for channel ch

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- $D_{ch}(x_j, x_k)$ is a similarity measure (χ^2 distance in our setup) for channel ch
- Problem: How to set each γ_{ch} ?

Weighting the channels

Image \rightarrow Sampler \times Local descriptor \times Spatial grid \Rightarrow Fusion \rightarrow Classification

- If we set γ_{ch} to $1/\sqrt{D_{ch}}$ we almost obtain (up to channels normalization) the method of Zhang et al.
 - This approach demonstrated remarkable performance in both VOC'05 and VOC'06
 - We submit this approach as the “flat” method
- As γ_{ch} controls the weight of channel ch in the sum, it can be used to select the most useful channels
 - We run a genetic algorithm to optimize per-task $\gamma_{ch,t}$ kernel parameters and also C_t SVM parameter
 - The learned channel weights are used for the “genetic” submission

Genetic algorithm to optimize SVM parameters

Image \rightarrow Sampler \times Local descriptor \times Spatial grid \Rightarrow Fusion \rightarrow Classification

- The genomes encode the optimized parameters
- In every iteration (generation)
 - 1 Random genomes are added to the pool (population)
 - 2 Cross-validation is used to evaluate the genomes (individuals) simultaneously for each class
 - 3 The more useful the genome is the more chance it has to be selected and combined with another good genome
 - 4 Information from combined genomes is randomly mixed (crossed) and forms the next generation
 - 5 To better avoid local minimas, random genes are altered (mutated)
- Useful genes and gene combinations survive and multiply

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Multiplying channels

| Channels ($\gamma_{ch} = 1/\overline{D_{ch}}$) | # | Average AP |
|--|----|------------|
| HS,LS × SIFT × 1,2x2 | 4 | 47.7 |
| HS,LS,DS × SIFT × 1,2x2 | 6 | 52.6 |
| HS,LS,DS × SIFT × 1,2x2,h3x1 | 9 | 53.3 |
| HS,LS,DS × SIFT,SIFT+hue × 1,2x2,h3x1 | 18 | 54.0 |
| HS,LS,DS × SIFT,SIFT+hue,PAS × 1,2x2,h3x1 | 21 | 54.2 |
| DS × SIFT,SIFT+hue,PAS × 1,2x2,h3x1 | 9 | 51.8 |

Table: Class-averaged AP on VOC'07 validation set

- Combination of interest points and dense sampling boosts the performance, color and 3x1 grid are important
- The performance monotonically increases with the number of channels
- Last experiments show, that anything sensible (HoGs, different vocabularies) further helps the performance

PASCAL VOC'07 Challenge results

| | INRIA (genetic) | INRIA (flat) | XRCE | TKK | QMUL (lspch) | QMUL (hsls) |
|--------------|-----------------|--------------|--------------|-------|--------------|-------------|
| aeroplane | 0.775 | 0.748 | 0.723 | 0.714 | 0.716 | 0.706 |
| bicycle | 0.636 | 0.625 | 0.575 | 0.517 | 0.550 | 0.548 |
| bird | 0.561 | 0.512 | 0.532 | 0.485 | 0.411 | 0.357 |
| boat | 0.719 | 0.694 | 0.689 | 0.634 | 0.655 | 0.645 |
| bottle | 0.331 | 0.292 | 0.285 | 0.273 | 0.272 | 0.278 |
| bus | 0.606 | 0.604 | 0.575 | 0.499 | 0.511 | 0.511 |
| car | 0.780 | 0.763 | 0.754 | 0.701 | 0.722 | 0.714 |
| cat | 0.588 | 0.576 | 0.503 | 0.512 | 0.551 | 0.540 |
| chair | 0.535 | 0.531 | 0.522 | 0.517 | 0.474 | 0.466 |
| cow | 0.426 | 0.411 | 0.390 | 0.323 | 0.359 | 0.366 |
| dining table | 0.549 | 0.540 | 0.468 | 0.463 | 0.374 | 0.344 |
| dog | 0.458 | 0.428 | 0.453 | 0.415 | 0.415 | 0.399 |
| horse | 0.775 | 0.765 | 0.757 | 0.726 | 0.715 | 0.715 |
| motorbike | 0.640 | 0.623 | 0.585 | 0.602 | 0.579 | 0.554 |
| person | 0.859 | 0.845 | 0.840 | 0.822 | 0.808 | 0.806 |
| potted plant | 0.363 | 0.353 | 0.326 | 0.317 | 0.156 | 0.158 |
| sheep | 0.447 | 0.413 | 0.397 | 0.301 | 0.333 | 0.358 |
| sofa | 0.506 | 0.501 | 0.509 | 0.392 | 0.419 | 0.415 |
| train | 0.792 | 0.776 | 0.751 | 0.711 | 0.765 | 0.731 |
| tv/monitor | 0.532 | 0.493 | 0.495 | 0.410 | 0.459 | 0.455 |
| average | 0.594 | 0.575 | 0.556 | 0.517 | 0.512 | 0.503 |

Learning channel weights (VOC'07 results)

| | HS | LS | DS | SIFT | +hue | PAS | 1 | 2x2 | h3x1 | C | flat | genetic |
|--------------|-----|-----|-----|------|------|------|-----|-----|------|-----|-------|--------------|
| aeroplane | 0.7 | 1.5 | 2.8 | 0.04 | 0.09 | 0.29 | 5.7 | 3.1 | 4.3 | 897 | 0.748 | 0.775 |
| bicycle | 0.7 | 1.5 | 2.8 | 0.04 | 0.09 | 0.12 | 5.7 | 1.0 | 4.3 | 521 | 0.625 | 0.636 |
| bird | 0.7 | 1.5 | 4.3 | 0.04 | 0.09 | 0.12 | 5.7 | 1.0 | 4.3 | 141 | 0.512 | 0.561 |
| boat | 0.2 | 1.5 | 4.3 | 0.12 | 0.03 | 0.12 | 5.7 | 1.0 | 4.3 | 897 | 0.694 | 0.719 |
| bottle | 0.7 | 1.5 | 1.5 | 0.09 | 0.09 | 0.12 | 5.7 | 3.1 | 4.3 | 897 | 0.292 | 0.331 |
| bus | 0.2 | 1.5 | 1.5 | 0.09 | 0.03 | 0.29 | 1.5 | 7.3 | 4.3 | 6 | 0.604 | 0.606 |
| car | 0.7 | 1.5 | 4.3 | 0.09 | 0.09 | 0.29 | 5.7 | 0.1 | 4.3 | 521 | 0.763 | 0.780 |
| cat | 0.7 | 1.5 | 2.8 | 0.04 | 0.03 | 0.12 | 5.7 | 3.1 | 4.3 | 19 | 0.576 | 0.588 |
| chair | 2.5 | 1.5 | 2.8 | 0.09 | 0.09 | 0.29 | 5.7 | 3.1 | 4.3 | 19 | 0.531 | 0.535 |
| cow | 0.2 | 1.5 | 4.3 | 0.04 | 0.09 | 0.29 | 5.7 | 3.1 | 4.3 | 897 | 0.411 | 0.426 |
| dining table | 0.2 | 1.5 | 4.3 | 0.12 | 0.02 | 0.29 | 5.7 | 3.1 | 4.3 | 6 | 0.540 | 0.549 |
| dog | 0.2 | 1.5 | 4.3 | 0.12 | 0.09 | 0.07 | 5.7 | 3.1 | 4.3 | 6 | 0.428 | 0.458 |
| horse | 0.7 | 1.5 | 4.3 | 0.09 | 0.03 | 0.12 | 5.7 | 0.1 | 4.3 | 521 | 0.765 | 0.775 |
| motorbike | 0.7 | 1.5 | 4.3 | 0.04 | 0.03 | 0.12 | 1.5 | 3.1 | 4.3 | 897 | 0.623 | 0.640 |
| person | 0.2 | 1.5 | 7.9 | 0.12 | 0.09 | 0.29 | 5.7 | 1.0 | 4.3 | 141 | 0.845 | 0.859 |
| potted plant | 2.5 | 1.5 | 4.3 | 0.04 | 0.09 | 0.29 | 5.7 | 3.1 | 4.3 | 19 | 0.353 | 0.363 |
| sheep | 0.2 | 1.5 | 4.3 | 0.12 | 0.03 | 0.29 | 5.7 | 0.1 | 4.3 | 6 | 0.413 | 0.447 |
| sofa | 2.5 | 0.7 | 4.3 | 0.04 | 0.03 | 0.05 | 5.7 | 3.1 | 4.3 | 141 | 0.501 | 0.506 |
| train | 0.7 | 1.5 | 4.3 | 0.12 | 0.09 | 0.29 | 5.7 | 0.1 | 4.3 | 897 | 0.776 | 0.792 |
| tv/monitor | 2.5 | 0.7 | 4.3 | 0.04 | 0.03 | 0.12 | 5.7 | 3.1 | 4.3 | 19 | 0.493 | 0.532 |

Summary

- We have shown that using a large number of channels helps recognition due to complementary information
- We have demonstrated how it is possible to generate tens of useful channels
- We have proposed to use a genetic algorithm to discover the most useful channels on per-class basis
- The experimental results show excellent performance

Thank you for your attention

I will be glad to answer your questions